

**Low Cross Talk and
Impedance Controlled Electrical Connector**

Cross-Reference to Related Applications

This application is a continuation of U.S. Patent Application number
5 08/903,762 filed on July 31, 1997, currently pending, which is a
continuation of U.S. Patent Application number 08/842,197 filed on April
23, 1997, now U.S. Patent number 5,741,144, which is a continuation of
U.S. Patent Application number 08/452,020 filed on June 12, 1995, now
abandoned, all of which are herein incorporated by reference.

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Background of the Invention

1. Field of the Invention

The present invention relates to electrical connectors and more
particularly to electrical connectors including means for controlling
electrical cross talk and impedance.

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2. Brief Description of Earlier Developments

As the density of interconnects increases and the pitch between
contacts approaches .025 inches or .5mm, the close proximity of the
contacts increases the likelihood of strong electrical cross talk coupling
between the contacts. In addition, maintaining design control over the
20 electrical characteristic impedance of the contacts becomes increasingly
difficult. In most interconnects, the mated plug/receptacle contact is
surrounded by structural plastic with air spaces to provide mechanical
clearances for the contact beam. As is disclosed in U. S. Patent No.
5,046,960 to Fedder, these air spaces can be used to provide some control
25 over the characteristic impedance of the mated contact. Heretofore,
however, these air spaces have not been used, in conjunction with the
plastic geometry, to control both impedance and, more importantly, cross
talk. Clearly, there is room for improvement in the art.

Summary of the Invention

These and other objects of the present invention are achieved in one aspect of the present invention by an electrical connector, comprising: a dielectric base; a plurality of ground or power contacts in the dielectric base; a plurality of signal contacts in the dielectric base and angled relative to the ground or power contacts; and a plurality of solder balls secured to the mounting ends of the ground or power contacts and the signal contacts. Each contact has a mating portion for engaging a contact on a mating connector and a mounting portion for securing the connector to a substrate.

These and other objects of the present invention are achieved in another aspect of the present invention by an electrical connector, comprising: an insulative housing having a plurality of apertures extending therethrough; a plurality of contacts in the apertures; and a plurality of solder balls secured to the mounting ends of the contacts.

These and other objects of the present invention are achieved in another aspect of the present invention by an electrical connector, comprising: an insulative housing with a mating face positionable adjacent a mating connector and a mounting face positionable adjacent a substrate; at least one contact extending between the mating face and the mounting face of the insulative housing and including a tail portion; and a solder mass secured to the tail portion for securing the electrical connector to the substrate.

Brief Description of the Drawings

Other uses and advantages of the present invention will become apparent to those skilled in the art upon reference to the specification and the drawings, in which:

Figure 1 is a schematic illustration of one preferred embodiment of the connector of the present invention;

Figure 1a is a schematic illustration of another preferred embodiment of the connector of the present invention;

5 Figure 2 is a schematic illustration of another preferred embodiment of the connector of the present invention;

Figure 3 is another schematic illustration of the connector illustrated in Figure 2;

10 Figure 4 is a side elevational view of another preferred embodiment of the connector of the present invention;

Figure 5 is an end view of the connector shown in Figure 4;

Figure 6 is a perspective view of the connector shown in Figure 4;

Figure 7 is an end view of the receptacle element of the connector shown in Figure 4;

15 Figure 8 is a bottom plan view of the receptacle element shown in Figure 7;

Figure 9 is a cross sectional view taken through IX - IX in Figure 7;

Figure 10 is an end view of the receptacle element of the preferred embodiment of the present invention shown in Figure 4;

20 Figure 11 is a bottom plan view of the receptacle element shown in Figure 10;

Figure 12 is a cross sectional view taken through XII - XII in Figure 10;

Figure 13 is a perspective view of the receptacle element shown in Figure 10;

25 Figure 14 is a cross sectional view of the plug and receptacle elements of the connector shown in Figure 4 prior to engagement;

Figure 15 is a cross sectional view taken through XV - XV in Figure 4;

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Figure 16 is a cross sectional view corresponding to Figure 13 of another preferred embodiment of the connector of the present invention;

Figures 17 and 18 are graphs illustrating the results of comparative tests described hereafter;

5 Figure 19 is a perspective view of a preferred embodiment of a cable assembly of the present invention;

Figure 20 is a detailed view of the area within circle XVIII in Figure 17;

Figure 21 is a cross sectional view of another preferred embodiment of a cable assembly of the present invention;

10 Figure 22 is a side elevational view of the cable assembly shown in Figure 17 in use with a receptacle;

Figure 23 is a cross sectional view taken through XXIII - XXIII in Figure 20.

Figure 24 is a top plan view of a plug section of another preferred
15 embodiment of the connector of the present invention;

Figure 25 is a bottom plan view of the plug section shown in Figure 24;

Figure 26 is an end view of the plug section shown in Figure 24;

Figure 27 is a side elevational view of the plug section shown in Figure
24;

20 Figure 28 is a top plan view of a receptacle section which is engageable with the plug section of a preferred embodiment of the present invention shown in Figure 24;

Figure 29 is a bottom plan view of the receptacle shown in Figure 28;

Figure 30 is an end view of the receptacle shown in Figure 28;

25 Figure 31 is a side elevational view of the receptacle shown in Figure 28;

Figure 32 is a fragmented cross sectional view as taken through lines

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XXXII - XXXII in Figures 24 and 28 showing those portions of the plug and receptacle shown in those drawings in an unengaged position; and

Figure 33 is a fragmented cross sectional view as would be shown as taken through lines XXXIII - XXXIII in Figures 24 and 28 if those

5 elements were engaged.

Detailed Description of the Preferred Embodiments

THEORETICAL MODEL

The basic I-beam transmission line geometry is shown in Figure 1.

10 The description of this transmission line geometry as an I-beam comes from the vertical arrangement of the signal conductor shown generally at numeral 10 between the two horizontal dielectric layers 12 and 14 having a dielectric constant ϵ and ground planes 13 and 15 symmetrically placed at the top and bottom edges of the conductor. The sides 20 and 22 of the conductor are open to the air 24 having an air dielectric constant ϵ_0 .

15 In a connector application, the conductor would be comprised of two sections 26 and 28 which abut end to end or face to face. The thickness, t_1 and t_2 of the dielectric layers 12 and 14, to first order, controls the characteristic impedance of the transmission line and the aspect ratio of the overall height h to dielectric width w_d controls the electric and
20 magnetic field penetration to an adjacent contact. The aspect ratio to minimize coupling beyond A and B is approximately unity as illustrated in Figure 1. The lines 30, 32, 34, 36 and 38 in Figure 1 are equipotentials of voltage in the air-dielectric space.

25 Taking an equipotential line close to one of the ground planes and following it out towards the boundaries A and B, it will be seen that both boundary A or boundary B are very close to the ground potential. This means that at both boundary A and boundary B we have virtual ground

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surfaces and if two or more I-beam modules are placed side by side, a virtual ground surface exists between the modules and there will be no coupling between the modules. In general, the conductor width w_c and dielectric thickness should be small compared to the dielectric width or module pitch.

Given the mechanical constraints on a practical connector design, the proportioning of the signal conductor (blade/beam contact) width and dielectric thicknesses will, of necessity, deviate somewhat from the preferred ratios and some minimal coupling will exist between adjacent signal conductors. However, designs using the basic I-beam guidelines will have lower cross talk than more conventional approaches.

Referring to Figure 1a, an alternate embodiment is shown in which the dielectric is shown at 12' and 14' with their respective ground planes at 13' and 15'. In this embodiment the conductor 26' and 28' extend respectively from dielectric layers 12' and 14', but the conductors 26' and 28' abut side to side rather than edge to edge.

An example of a practical electrical and mechanical I-beam design for a .025 inch pitch connector uses 8 x 8 mil beams 26" and 8 x 8 mil blades 28", which when mated, form an 8 x 16 mil signal contact and the contact cross-section is shown in Figure 2. The dielectric thickness, t , is 12 mils. The voltage equipotentials for this geometry are shown in Figure 3 where virtual grounds are at the adjacent contact locations and some coupling will now exist between adjacent contacts.

Referring to Figure 2, the I-beam transmission geometry is shown as being adapted to a less than ideally proportioned multi-conductor system. Signal conductors 40, 42, 44, 46 and 48 extend perpendicularly between two dielectric and horizontal ground planes 50 and 52 which

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have a dielectric ϵ . To the sides of the conductors are air spaces 54, 56, 58, 60, 62 and 64.

Referring to Figure 3, another multi-conductor connector is shown wherein there are parallel conductors 66, 68 and 70 which extend
5 perpendicularly between two dielectric and horizontal ground planes 72 and 74. To the sides of the conductors are air spaces 76, 78, 80 and 82.

ELECTRICAL CONNECTOR

Referring particularly to Figures 4-12 it will be seen that the connector of the present invention is generally comprised of a plug shown
10 generally at numeral 90 and a receptacle shown generally at numeral 92. The plug consists of a preferably metallic plug housing 94 which has a narrow front section 96 and a wide rear section 98. The front section has a top side 100 and a bottom side 102. The wide rear section has a top side 104 and a bottom side 106. The plug also has end surfaces 108 and
15 110.

On the top side of both the front and rear sections there are longitudinal grooves 112, 114, 116 and 118 and 119. In these grooves there are also apertures 120, 122, 124, 126 and 128. Similarly on the bottom sides of both the front and rear section there are longitudinal
20 grooves as at 128 which each have apertures as at 130. On the top sides there is also a top transverse groove 132, while on the bottom side there is a similarly positioned bottom transverse groove 134. The plug also has rear standoffs 136 and 138.

Referring particularly to Figure 9 it will be seen that the plug includes
25 a dielectric element 140 which has a rear upward extension 142 and a rear downward extension 144 as well as a major forward extension 146 and a minor forward extension 148. The housing also includes opposed

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downwardly extending projection 150 and upwardly extending projection 152 which assist in retaining the dielectric in its position.

In the longitudinal grooves on the top side of the plug there are top axial ground springs 154, 156, 158, 160 and 162. In the transverse
5 groove there is also a top transverse ground spring 164. This transverse ground spring is fixed to the housing by means of ground spring fasteners 166, 168, 170 and 172.

At the rearward terminal ends of the longitudinal ground springs there are top grounding contacts 176, 178, 180, 182 and 184. Similarly the
10 grooves on the bottom side of the plug there are bottom longitudinal ground springs 186, 188, 190, 192 and 194.

In the bottom transverse groove there is a bottom transverse ground spring 196 as with the top transverse ground spring, this spring is fixed in the housing by means of ground spring fasteners 198, 200, 202, 204
15 and 206. At the rear terminal ends of the ground springs there are bottom ground contacts 208, 210, 212, 214 and 216.

The plug also includes a metallic contact section shown generally at 218 which includes a front recessed section 220, a medial contact section 222 and a rearward signal pin 224. An adjacent signal pin is shown at
20 226. Other signal pins are shown, for example, in Figure 7 at 228, 230, 232, 234 and 236. These pins pass through slots in the dielectric as at 238, 240, 242, 244, 246, 248 and 250.

The dielectric is locked in place by means of locks 252, 254, 256 and 258 which extend from the metal housing. Referring again particularly to
25 Figure 9 the plug includes a front plug opening 260 and top and bottom interior plug walls 262 and 264. It will also be seen from Figure 9 that a

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convex section of the ground springs as at 266 and 268 extend through the apertures in the longitudinal grooves.

Referring particularly to Figures 10-12, it will be seen that the receptacle includes a preferably metallic receptacle housing 270 with a narrow front section 272 and a wider rear section 274. The front section has a topside 276 and a bottom side 278 and the rear section has a topside 280 and 282. The receptacle also has opposed ends 284 and 286. On the top sides of the receptacle there are longitudinal grooves 288, 290 and 292. Similarly on the bottom surface there are longitudinal grooves as at 294, 296 and 298. On the top surface there are also apertures as at 300, 302 and 304. On the bottom surface there are several apertures as at 306, 308 and 310. The receptacle also includes rear standoffs 312 and 314.

Referring particularly to Figure 12, the receptacle includes a dielectric element shown generally at numeral 316 which has a rear upward extension 318, a rear downward extension 320, a major forward extension 322 and a minor forward extension 324. The dielectric is retained in position by means of downward housing projection 326 and upward interior housing projection 328 along with rear retaining plate 330. Retained within each of the apertures there is a ground spring as at 332 which connects to a top ground post 334. Other top ground posts as at 336 and 338 are similarly positioned. Bottom ground springs as at 340 are connected to ground posts as at 342 while other ground posts as at 344 and 346 are positioned adjacent to similar ground springs.

Referring particularly to Figure 12, the receptacle also includes a metallic contact section shown generally at numeral 348 which has a front recess section 350, a medial contact section 352 and a rearward

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signal pin 354. An adjacent pin is shown at 356. These pins extend rearwardly through slots as at 358 and 360. The dielectric is further retained in the housing by dielectric locks as at 362 and 364. The receptacle also includes a front opening 365 and an interior housing surface 366. Referring particularly to Figure 13, this perspective view of the receptacle shows the structure of the metallic contact section 350 in greater detail to reveal a plurality of alternating longitudinal ridges as at 367 and grooves 368 as at which engage similar structures on metallic contact 218 of the receptacle.

Referring particularly to Figures 14 and 15, the plug and receptacle are shown respectively in a disengaged and in an engaged configuration. It will be observed that the major forward extension 146 of the dielectric section of the plug abuts the minor forward extension of the dielectric section of the receptacle end to end. The major forward extension of the dielectric section of the receptacle abuts the minor forward extension of the dielectric section of the plug end to end.

It will also be observed on the metallic section of the plug the terminal recess receives the metallic element of the receptacle in side by side abutting relation. The terminal recess of the metallic contact element of the receptacle receives the metallic contact element of the plug in side by side abutting relation. The front end of the terminal housing abuts the inner wall of the plug. The ground springs of the plug also abut and make electrical contact with the approved front side walls of the receptacle.

It will be noted that when the connector shown in Figure 15 where the plug and receptacle housings are axially engaged, the plug metallic contact and receptacle metallic contact extend axially inwardly.

respectively from the plug dielectric element and the receptacle dielectric element to abut each other. It will also be noted that the plug and receptacle dielectric elements extend radially outwardly respectfully from the plug and receptacle metallic contact elements.

5 Referring to Figure 16, it will be seen that an alternate embodiment of the connector of the present invention is generally comprised of a plug shown generally at numerals 590 and a receptacle shown generally at numerals 592. The plug consists of a plug housing 594. There is also a plug ground contact 596, plug ground spring 598, plug signal pins 600 and 602, plug contact 606 and dielectric insert 608.

10 The receptacle consists of receptacle housing 610, receptacle ground contact 612, receptacle ground springs 614 and receptacle contact 616. An alignment frame 618 and receptacle signal pins 620 and 622 are also provided. It will be appreciated that this arrangement affords the same I-beam geometry as was described above.

COMPARATIVE TEST

15 The measured near end (NEXT) and far end (FEXT) cross talk at the rise time of 35p sec, for a .05" pitch scaled up model of a connector made according to the foregoing first described embodiment are shown in Figure 17. The valley in the NEXT wave form of approximately 7% is the near end cross talk arising in the I-beam section of the connector. The leading and trailing peaks come from cross talk at the input and output sections of the connector where the I-beam geometry cannot be maintained because of mechanical constraints.

25 The cross talk performance for a range of risetimes greater than twice the delay through the connector of the connector relative to other connector systems is best illustrated by a plot of the measured rise time-

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cross talk product (nanoseconds percent) versus signal density (signals/inch). The different signal densities correspond to different signal to ground ratio connections in the connector.

The measured rise time-cross talk product of the scaled up .05" pitch model I-beam connector is shown in Figure 18 for three signal to ground ratios; 1:1, 2:1, and all signals. Since the cross talk of the scaled up model is twice that of the .025 inch design, the performance of the .025 inch pitch, single row design is easily extrapolated to twice the density and one half the model cross talk. For the two row design, the density is four times that of the model and the cross talk is again one half. The extrapolated performance of the one row and two row .025 inch pitch connectors are also shown in Figure 18 relative to that of a number of conventional connectors as are identified in that figure. The rise time cross talk product of the .025 inch pitch I-beam connector for all signals is .75 and is much less than that of the other interconnects at correspondingly high signal to ground ratios.

ELECTRICAL CABLE ASSEMBLY

Referring to Figures 19 and 20, it will be seen that the beneficial results achieved with the connector of the present invention may also be achieved in a cable assembly. That is, a dielectric may be extruded in an I-beam shape and a conductor may be positioned on that I-beam on the web and the horizontal flanges so as to achieve low cross talk as was described above. I-beam dielectric extrusions are shown at numerals 369 and 370. Each of these extensions has a web 371 which is perpendicularly interposed at its upper and lower edges between flanges as at 372 and 373.

The flanges have inwardly facing interior surfaces and outwardly facing exterior surfaces which have metallized top ground plane sections 374 and 376 and metallized bottom ground plane sections respectively at 378 and 380. The webs also have conductive layers on their lateral sides.

5 I-beam extrusion 370 has vertical signal lines 382 and 384 and I-beam extrusion 374 has vertical signal lines 386 and 388. These vertical signal lines and ground plane sections will preferably be metallized as for example, metal tape. It will be understood that the pair of vertical metallized sections on each extrusion will form one signal line.

10 The property of the I-beam geometry as it relates to impedance and cross talk control will be generally the same as is discussed above in connection with the connector of the present invention. Referring particularly to Figure 20, it will be seen that the I-beam extrusions have interlocking steps as at 390 and 392 to maintain alignment of each I-

15 beam element in the assembly. Referring to Figure 21, I-beam elements shown generally at 394, 396 and 398 are metallized (not shown) as described above and may be wrapped in a foil and elastic insulative jacket, shown generally at numeral 400.

20 Because of the regular alignment of the I-beam element in a collinear array, the I-beam cable assembly can be directly plugged to a receptacle without any fixturing of the cable except for removing the outer jacket of foil at the pluggable end. The receptacle can have contact beams which mate with blade elements made up of the ground and signal metallizations.

25 Referring particularly to Figure 23, it will be seen, for example, that the receptacle is shown generally at numeral 402 having signal contacts 404 and 406 received respectively vertical sections of I-beam elements 408

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23 and 410. Referring to Figure 22, the receptacle also includes ground contacts 412 and 414 which contact respectively the metallized top ground plane sections 416 and 418.

BALL GRID ARRAY CONNECTOR

- 5 The arrangement of dielectric and conductor elements in the I-beam geometry described herein may also be adapted for use in a ball grid array type electrical connector. A plug for use in such a connector is shown in Figures 24-27. Referring to these figures, the plug is shown generally at numeral 420. This plug includes a dielectric base section 422, a dielectric peripheral wall 424, metallic signal pins as at 426, 428, 430, 432 and 434 are arranged in a plurality of rows and extend perpendicularly upwardly from the base section.

10 Longitudinally extending metallic grounding or power elements 436, 438, 440, 442, 444 and 446 are positioned between the rows of signal

- 15 pins and extend perpendicularly from the base section. The plug also includes alignment and mounting pins 448 and 450. On its bottom side the plug also includes a plurality of rows of solder conductive tabs as at 452 and 454.

Referring to Figures 28-31, a receptacle which mates with the plug 420

- 20 is shown generally at numeral 456. This receptacle includes a base section dielectric 458, a peripheral ^{bevelled edge} recess 460 and rows of metallic pin receiving recesses as at 462, 464, 466, 468 and 470. Metallic grounding or power elements receiving structures 472, 474, 476, 478, 480 and 482 are interposed between the rows of pin receiving recesses. On its bottom side the receptacle also includes alignment and mounting pins 484 and 486 and rows of solder conductive pads as at 488 and 490. From Figures

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32-33 it will be observed that the same I-beam geometry as was described above is available with this arrangement.

5 It will be appreciated that electrical connector has been described which by virtue of its I-beam shaped geometry allows for low cross talk and impedance control.

It will also be appreciated that an electrical cable has also been described which affords low cross talk and impedance control by reason of this same geometry.

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10 While the present invention has been described in connection with the preferred embodiments of the various figures, it is to be understood that other similar embodiments may be used or modifications and additions may be made to the described embodiment for performing the same function of the present invention without deviating therefrom. Therefore, the present invention should not be limited to any single
15 embodiment, but rather construed in breadth and scope in accordance with the recitation of the appended claims.